

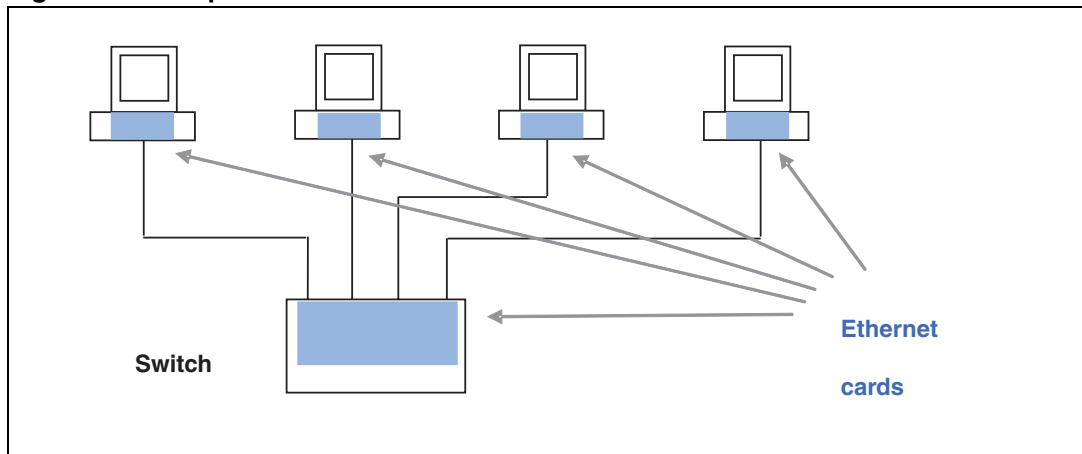
### 100 Mbps and Gigabit Ethernet protection

#### Introduction

Ethernet is the most commonly used technology for computer networking. This technology may be supported by copper pairs, coaxial cables or optical fibers. Copper infrastructure is preferred thanks to its lower cost of deployment.

As the data traffic keeps on growing, data rates of copper Ethernet technologies present on the market have increased also: from 10 Mbps (10Base-T), then 100 Mbps (100Base-T, called Fast Ethernet), to 1000 Mbps (1000Base-T, called Gigabit Ethernet).

**Figure 1. Simplified Ethernet network**



*Figure 1* shows a simplified Ethernet network (star configuration), in which each personal computer is connected to a concentrator, called a hub or server.

The link between each machine and the hub is done by means of twisted copper pairs and RJ45 connectors. The max length of this connexion is 100 m.

An Ethernet card is present in each machine and in the hub, and the transmission mode is full duplex.

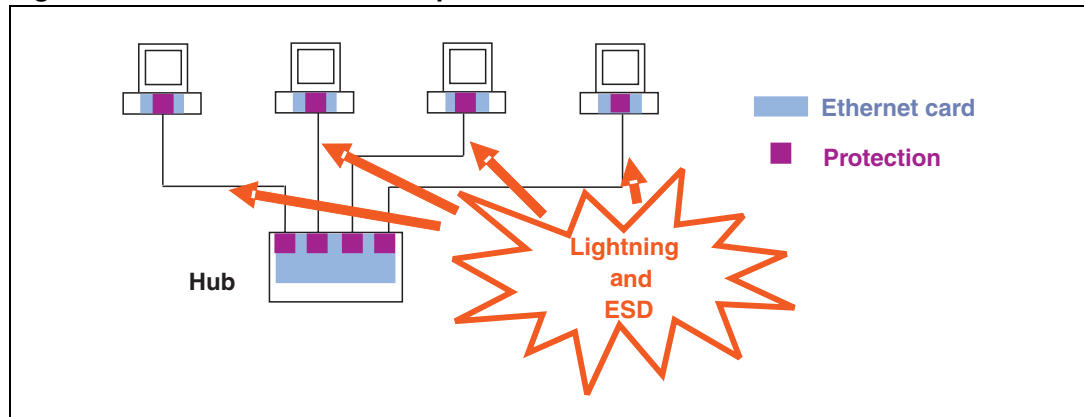
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# 1 Telecom disturbances

Figure 2 shows the previous Ethernet network when it is submitted to disturbances. These transients are mainly due to two kinds of disturbance. The first one occurs on outside lines and is linked to atmospheric effects (lightning). The second one happens on inside lines and is due to electrostatic discharge (ESD). Today, tests for withstanding these disturbances are defined in international standards.

**Figure 2. Line disturbance and protection location**

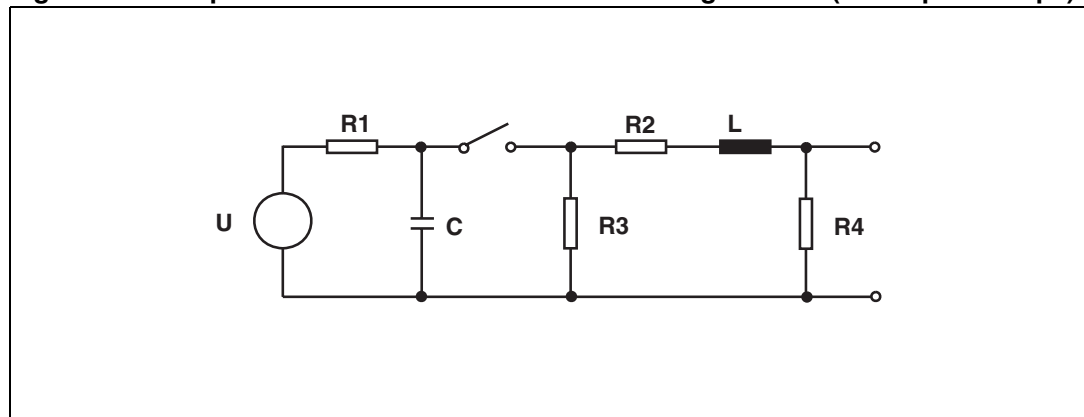


The standard used to qualify Ethernet equipment against lightning strikes is the IEC 61000-4-5 standard. This recommendation is based on the 1.2 / 50  $\mu$ s – 8 / 20  $\mu$ s combination waveform (1.2 / 50  $\mu$ s open-circuit voltage waveform and a 8 / 20  $\mu$ s short-circuit current waveform).

In Ethernet applications, Level 2 of this standard, which corresponds to 1 kV, is the most often required. The test series resistance to be considered is 42  $\Omega$  (40 + 2  $\Omega$  of generator internal resistance). Then, the equipment has to withstand a current of 24 A.

Figure 3, Table 1, and Figure 4 present the IEC 61000-4-5 surge test definition. First, a simplified circuit of the 1.2 / 50  $\mu$ s – 8 / 20  $\mu$ s combination wave generator is shown (Figure 3), then a table providing the open-circuit test voltage for each test level of the standard (Table 1), and finally an example of a test setup (Figure 4).

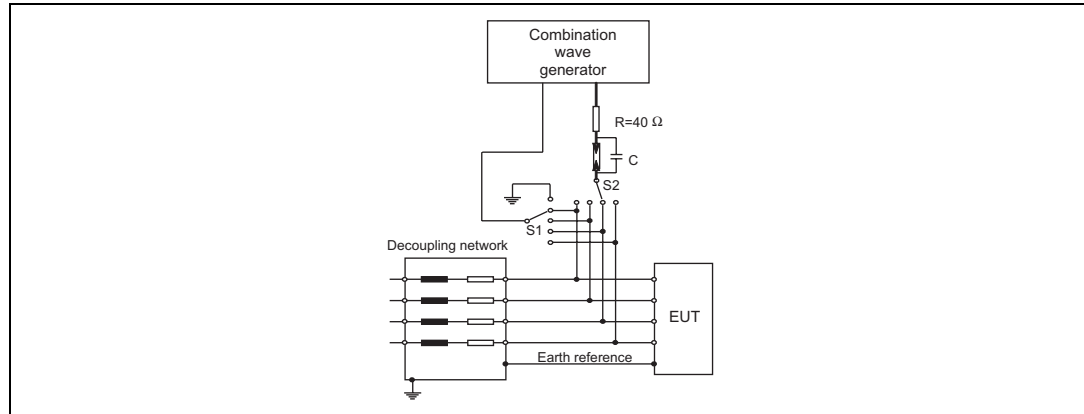
**Figure 3. Simplified circuit of the combination wave generator (1.2/50  $\mu$ s - 8/20  $\mu$ s)**



**Table 1. IEC 61000-4-5 surge test levels**

Level	Open-circuit test voltage (kV)
1	0.5
2	1.0
3	2.0
4	4.0

**Figure 4. IEC 61000-4-5 - simplified schematic of test setup**



The IEC 61000-4-5 standard requires five applications of each polarity on the equipment. This standard defines several acceptance criteria depending on the state of the equipment after the test (performance still ok, degradation of the performance, damage of the equipment).

Ethernet applications usually recommend the A criterion of IEC 61000-4-5. That is, normal performance of the equipment after test.

The most commonly used standard to qualify Ethernet equipment against ESD is the IEC 61000-4-2 standard.

[Table 2](#) gives the test voltage for each test level of the standard, for both contact and air discharge tests. Generally, Level 4 is required, i.e. the equipment has to withstand 8 kV contact and 15 kV air discharge.

Similarly, Ethernet applications usually recommend the A criterion of IEC 61000-4-2.

**Table 2. IEC 61000-4-2 test levels**

1a - contact discharge		1b - air discharge	
Level	Test voltage	Level	Test voltage
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15

## 2 SLVU2.8 protection devices

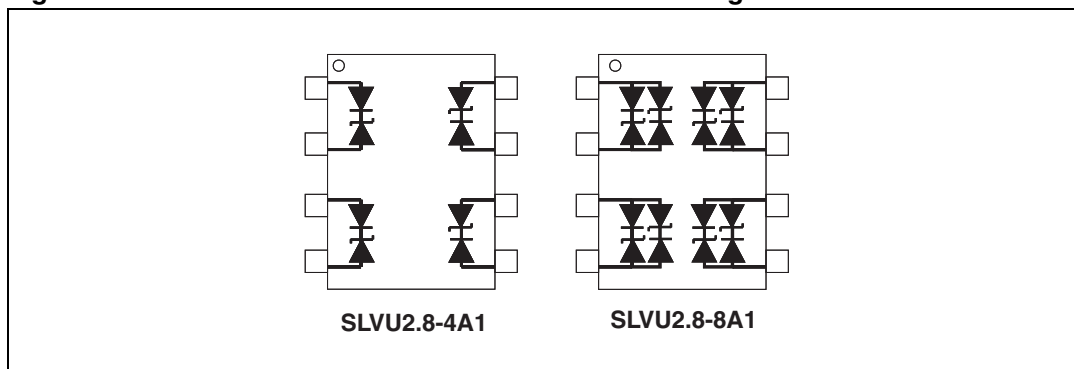
SLVU2.8 products are low voltage and low capacitance clamping protection devices.

There are two versions:

- SLVU2.8-4A1, which provides 2-line pair (four lines) bidirectional protection
- SLVU2.8-8A, which provides 4-line pair (eight lines) bidirectional protection.

Both are available in an SO-8 package.

**Figure 5. SLVU2.8-4A1 and SLVU2.8-8A1 functional diagrams**



*Figure 5* presents the SLVU2.8-4A1 and SLVU2.8-8A1 functional diagrams. Both diagrams show the presence of diodes that offer a low capacitance structure.

SLVU2.8-4A1 and SLVU2.8-8A1 present a typical capacitance of 3 pF that allow them to be compatible with 100 Mbps and Gigabit Ethernet lines since, in this way, they preserve the signal integrity.

Both devices are compliant with the IEC 61000-4-5 Level 2 requirements. That is, they are able to withstand a 24 A (8 / 20  $\mu$ s) surge current. They comply also with IEC 61000-4-2 Level 4 requirements. That is they can support 8 kV contact and 15 kV air discharges for ESD.

Thanks to low operating voltage (2.8 V @ 0.2  $\mu$ A) compatible with Ethernet applications, both devices offer a low clamping voltage: <15 V @ 24 A (8 / 20  $\mu$ s), which provides an efficient protection of the Ethernet transceiver.

The SLVU2.8-4A1 has a flow through design to minimize the track inductances and then to reduce the peak voltage during an ESD surge.

In the same way, the internal layout of the SLVU2.8-8A1 is optimized to minimize the track inductances and then to reduce the peak voltage during an ESD surge.

### 3 100 Mbps and Gigabit Ethernet protection circuits with SLVU2.8

Figure 6. 100 Mbps Ethernet protection with SLVU2.8-4A1

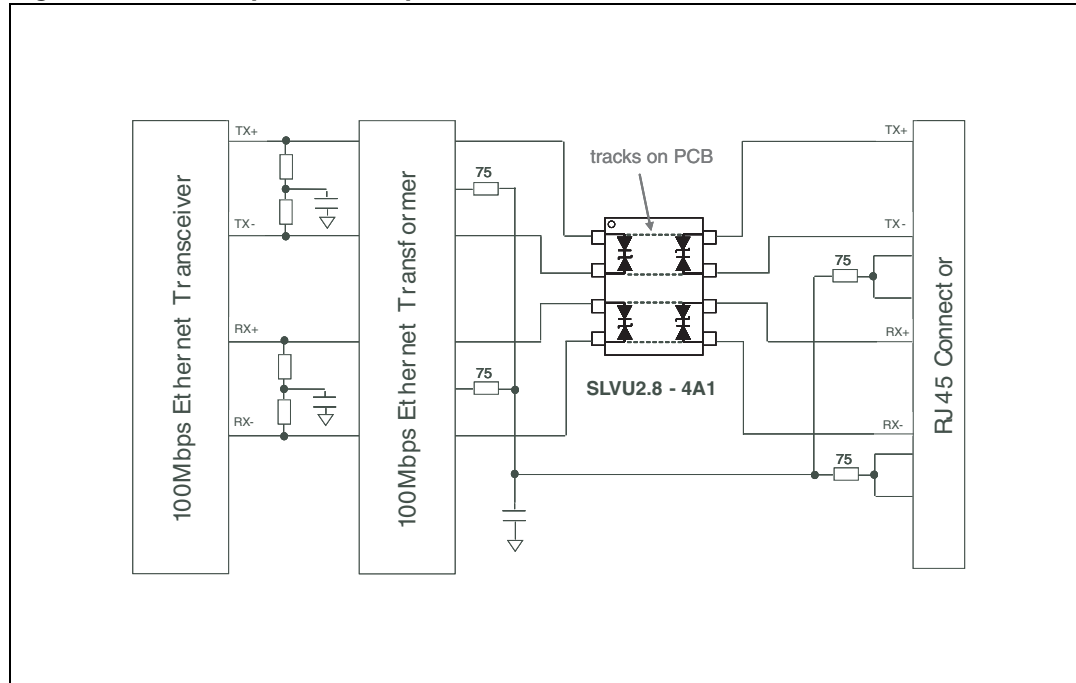
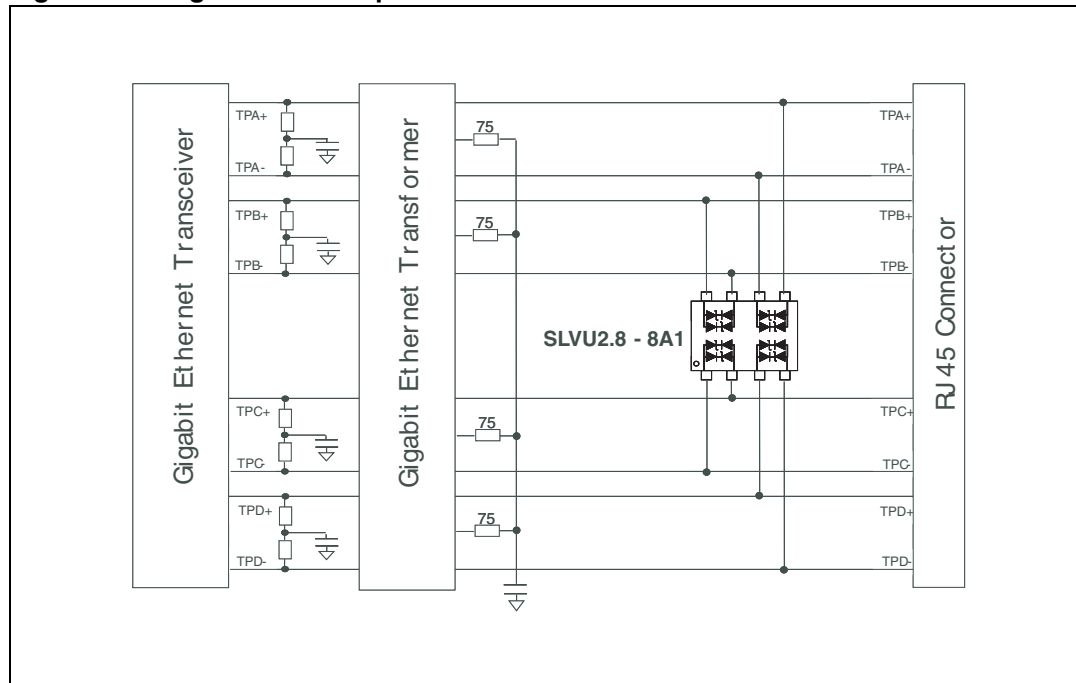


Figure 7. Gigabit Ethernet protection with SLVU2.8-8A1



Note that both SLVU2.8-4A1 and SLVU2.8-8A1 can protect 100 Mbps and Gigabit Ethernet circuits. [Figure 6](#) shows one SLVU2.8-4A1 protecting one 100 Mbps Ethernet port.

As the I/Os inside SLVU2.8-4A1 are not internally connected, note that the connections are assumed thanks to PCB tracks running under the SLVU2.8-4A1.

One SLVU2.8-8A1 can also be used to protect two 100 Mbps Ethernet ports. [Figure 7](#) shows one SLVU2.8-8A1 protecting one Gigabit Ethernet port.

Two SLVU2.8-4A1 can also be used to protect one Gigabit Ethernet port to offer a more convenient layout.

## 4 Board layout recommendation

Board layout must be carefully considered for the suppression of ESD events. Such very fast transients have a very high  $di/dt$ , and then the voltage across parasitic inductances located in the protection path may become very important ( $V = L \cdot di/dt$ ).

And finally the device to be protected will see not only the clamping voltage of the SLVU2.8 protection device, but also this high overvoltage.

Hence, we recommend the following layout considerations for an optimized protection:

- Put the SLVU2.8 protection device as close as possible to the RJ45 connector to reduce the transient coupling in nearby lines.
- Minimize the track length between the SLVU2.8 protection device and the line to be protected.
- Place ground planes wherever possible.



## 5 SLVU2.8 protection behavior

Figure 8. +1 kV (1.2 / 50  $\mu$ s with 42  $\Omega$ ) surge test performed on SLVU2.8-4A1

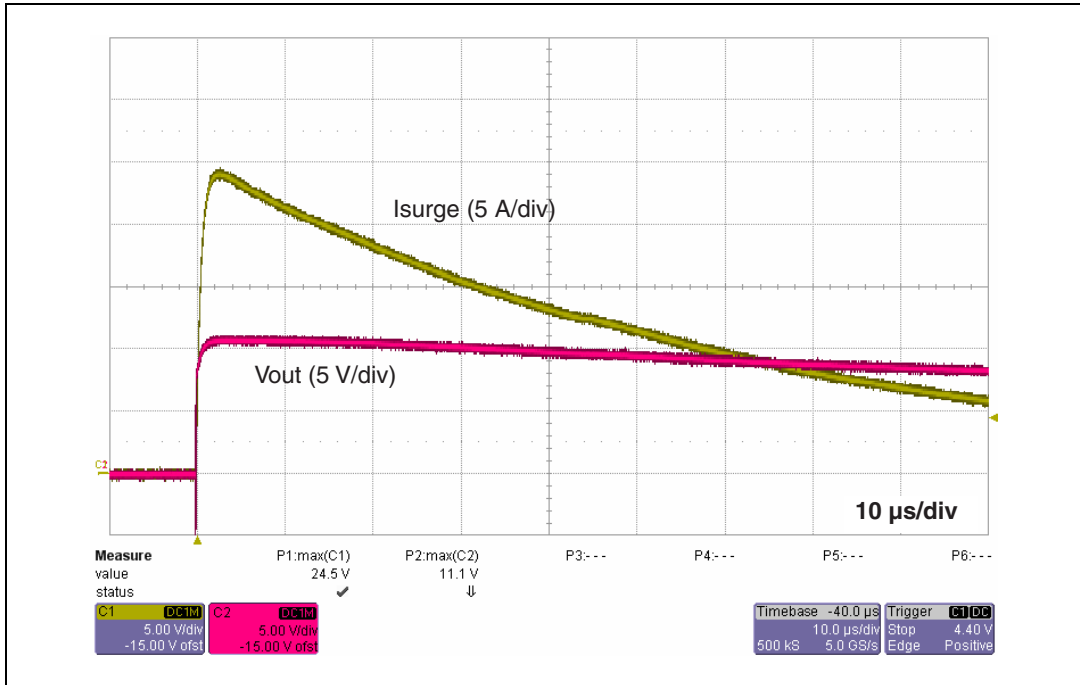


Figure 9. -1 kV (1.2 / 50  $\mu$ s with 42  $\Omega$ ) surge test performed on SLVU2.8-4A1

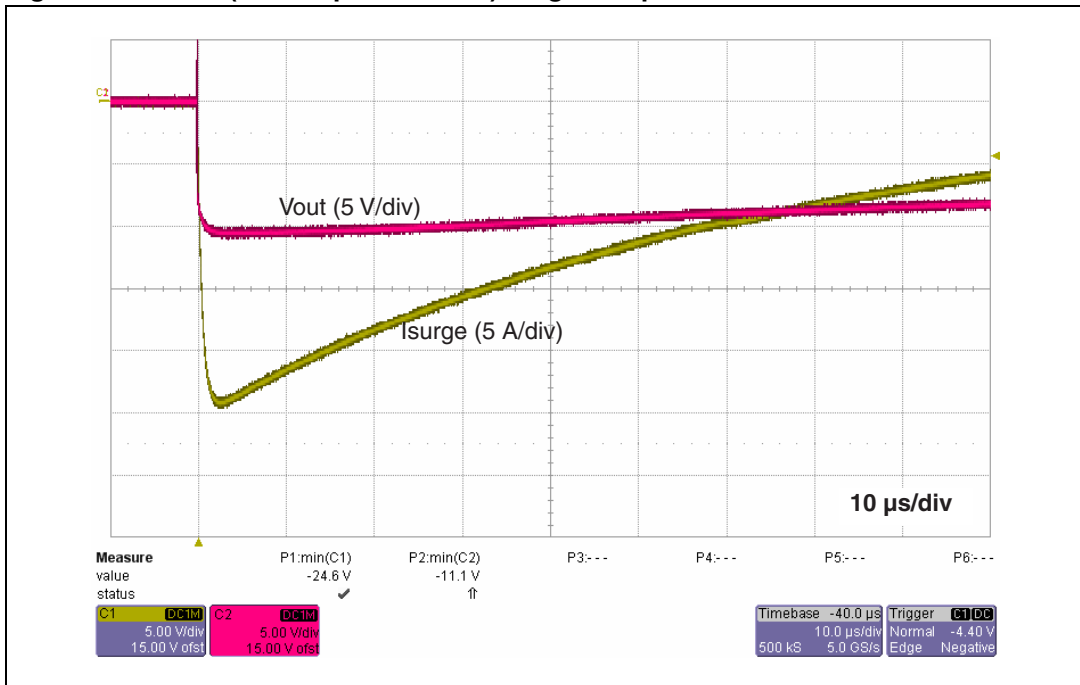


Figure 10. +1 kV (1.2 / 50  $\mu$ s with 42  $\Omega$ ) surge test performed on SLVU2.8-8A1

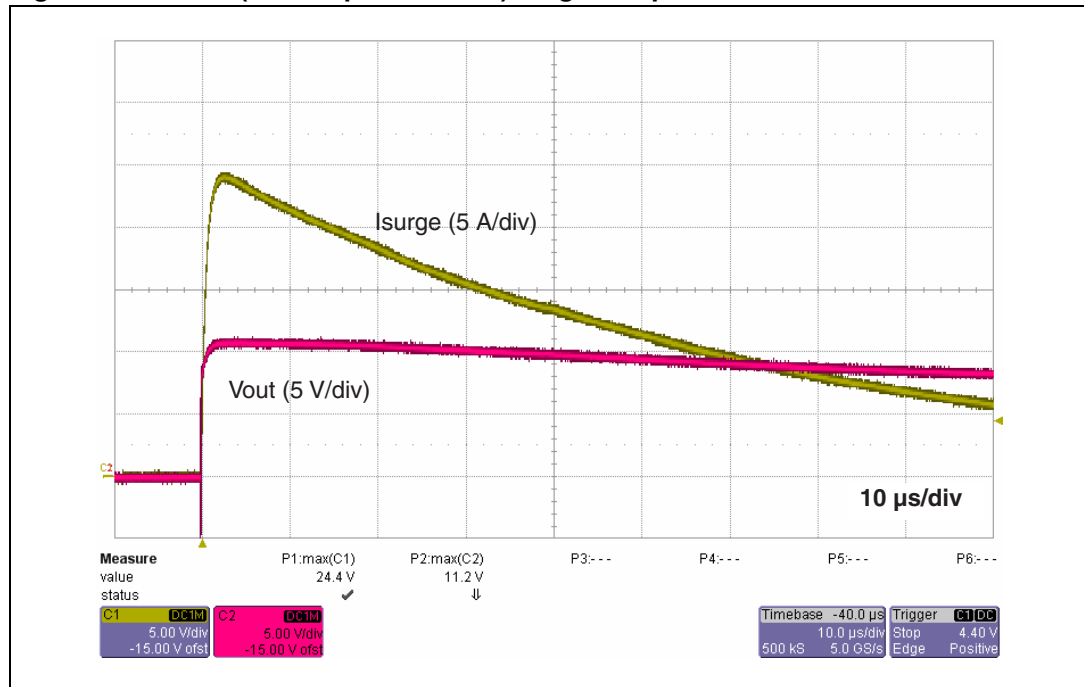
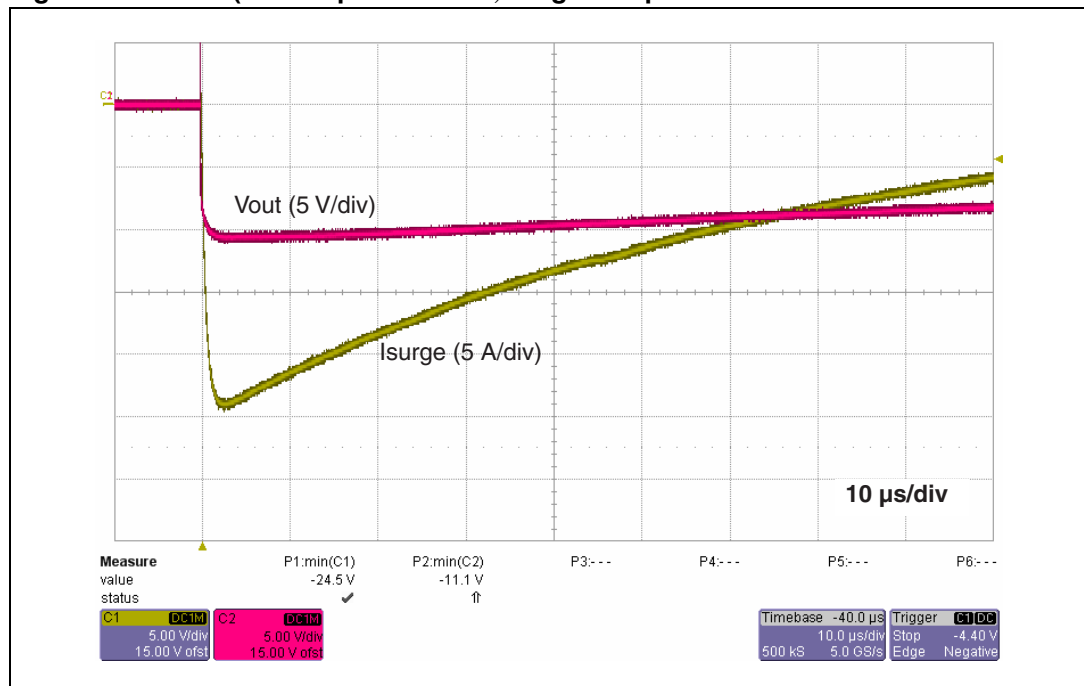


Figure 11. -1 kV (1.2 / 50  $\mu$ s with 42  $\Omega$ ) surge test performed on SLVU2.8-8A1



1.2 / 50  $\mu$ s surge tests have been performed with Keytek ECAT E510A surge generator.

Figure 8, 9, 10 and 11 show the protection level provided by both SLVU2.8-4A1 and SLVU2.8-8A1 when subject to  $\pm 1$  kV (1.2 / 50  $\mu$ s with 42  $\Omega$ ) lightning test, according to IEC 61000-4-5 Level 2 standard.

The maximum voltage across both SLVU2.8-4A1 and SLVU2.8-8A1 during these tests is about 15 V.

Note that having a 42 Ω test series resistance (instead of 2 Ω) generates a 2 / 50 μs current waveform instead of 8 / 20 μs. Both devices have been designed for this purpose.

Figure 12. +8 kV contact discharge test applied to SLVU2.8-4A1

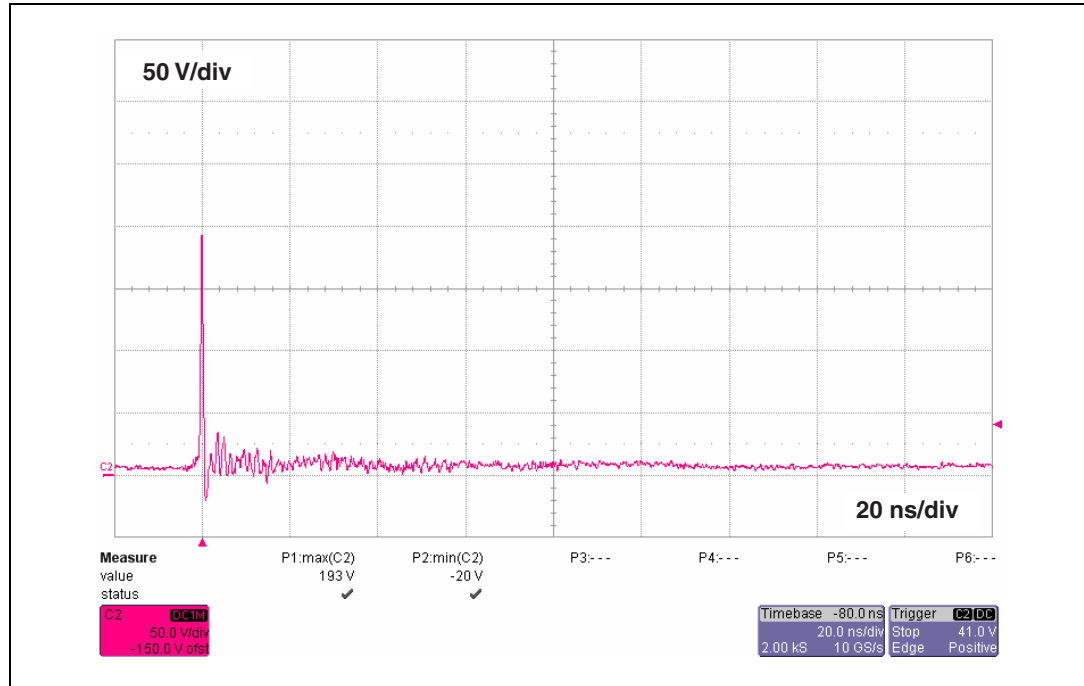


Figure 13. -8 kV contact discharge test applied to SLVU2.8-4A1

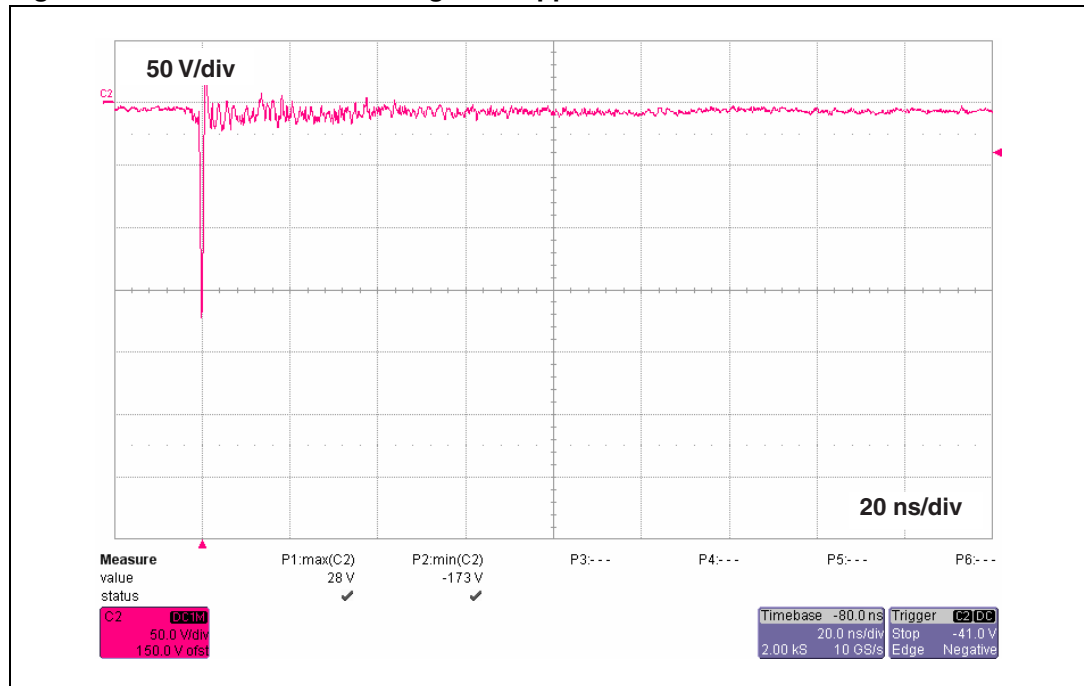


Figure 14. +15 kV air discharge test applied to SLVU2.8-4A1

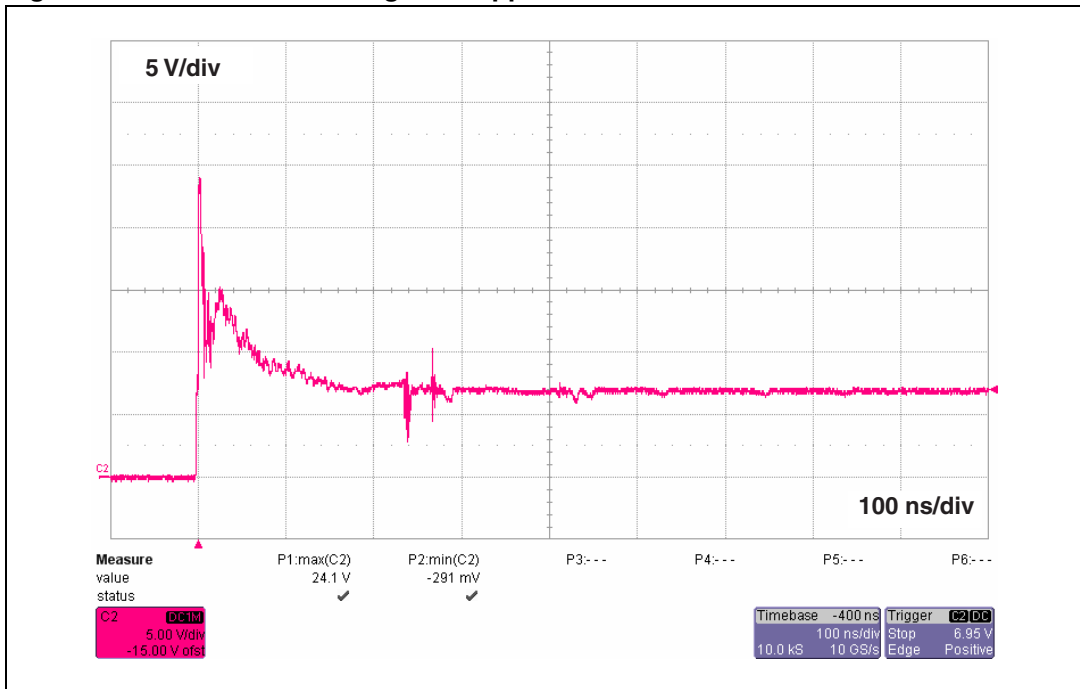
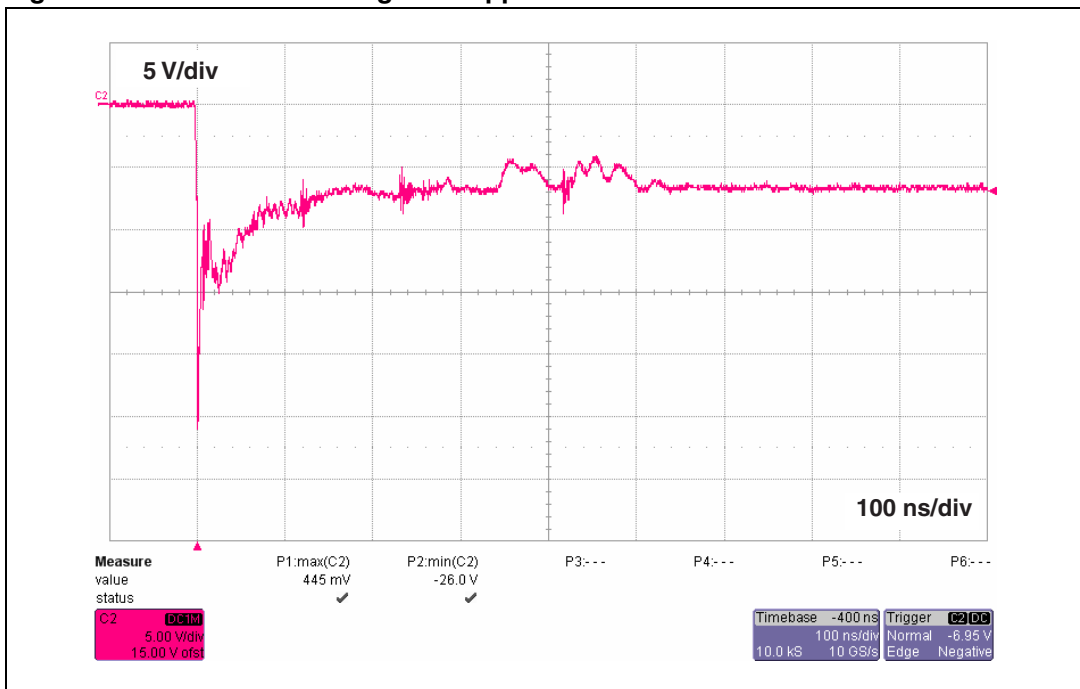


Figure 15. -15 kV air discharge test applied to SLVU2.8-4A1



ESD tests have been performed with Schaffner NSG438 ESD generator.

Figure 12, 13, 14 and 15 show the ESD response of SLVU2.8-4A1, respectively for + 8kV, -8 kV contact, +15 kV and -15 kV air discharges, according to IEC 61000-4-2 Level 4 standard.

The peak voltage across SLVU2.8-4A1 during a  $\pm 8$  kV contact discharge is about  $\pm 180$  V for a duration less than one nanosecond and then about a few volts.

The peak voltage across SLVU2.8-4A1 during a  $\pm 15$  kV air discharge is about  $\pm 25$  V for a few nanoseconds and then about a few volts.

Figure 16. +8 kV contact discharge test applied to SLVU2.8-8A1

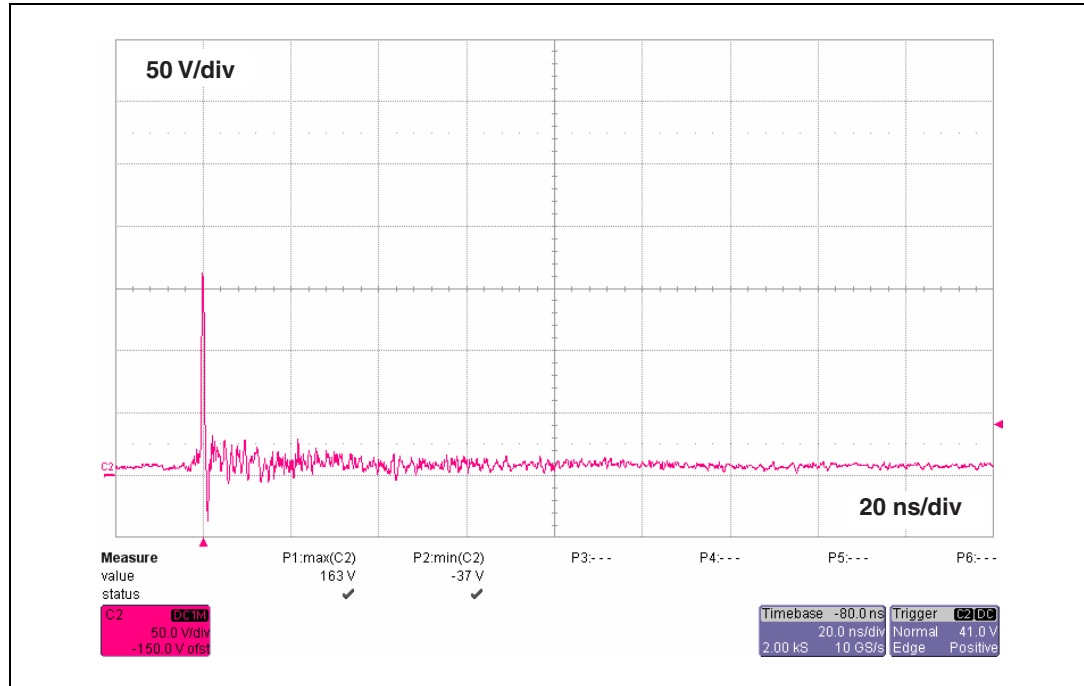


Figure 17. -8 kV contact discharge test applied to SLVU2.8-8A1

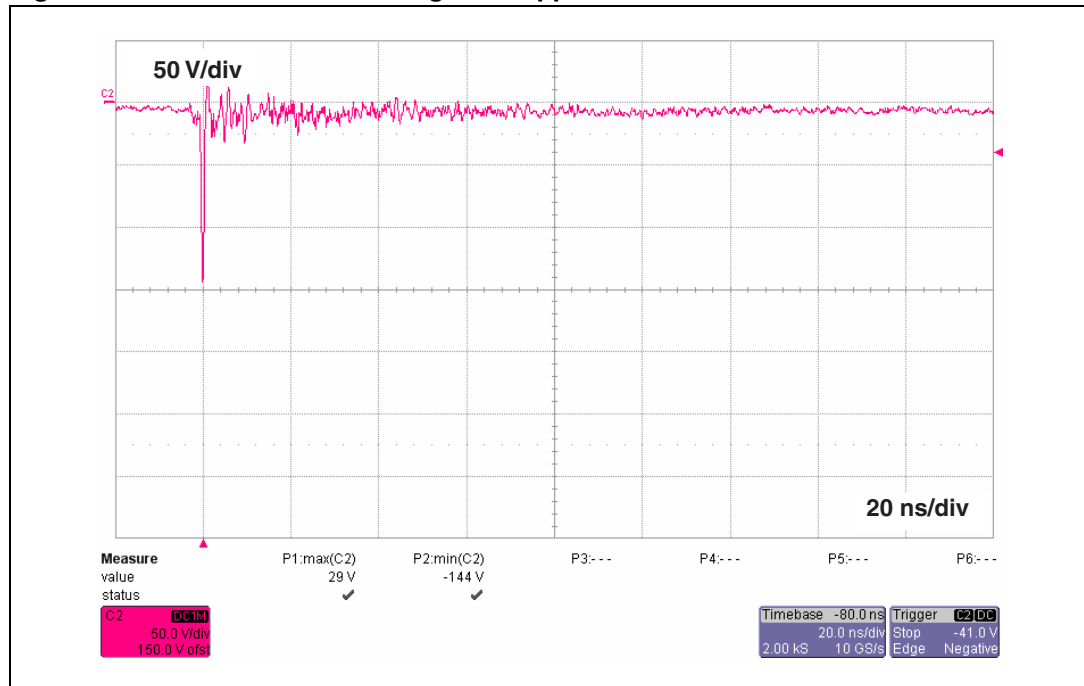


Figure 18. +15 kV air discharge test applied to SLVU2.8-8A1

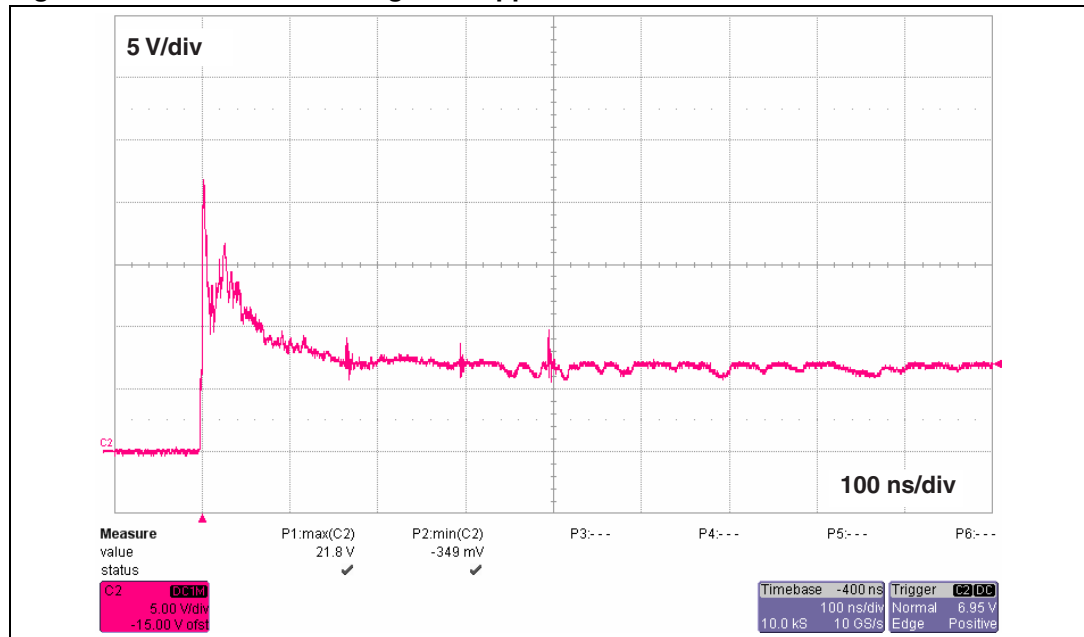


Figure 19. -15 kV air discharge test applied to SLVU2.8-8A1

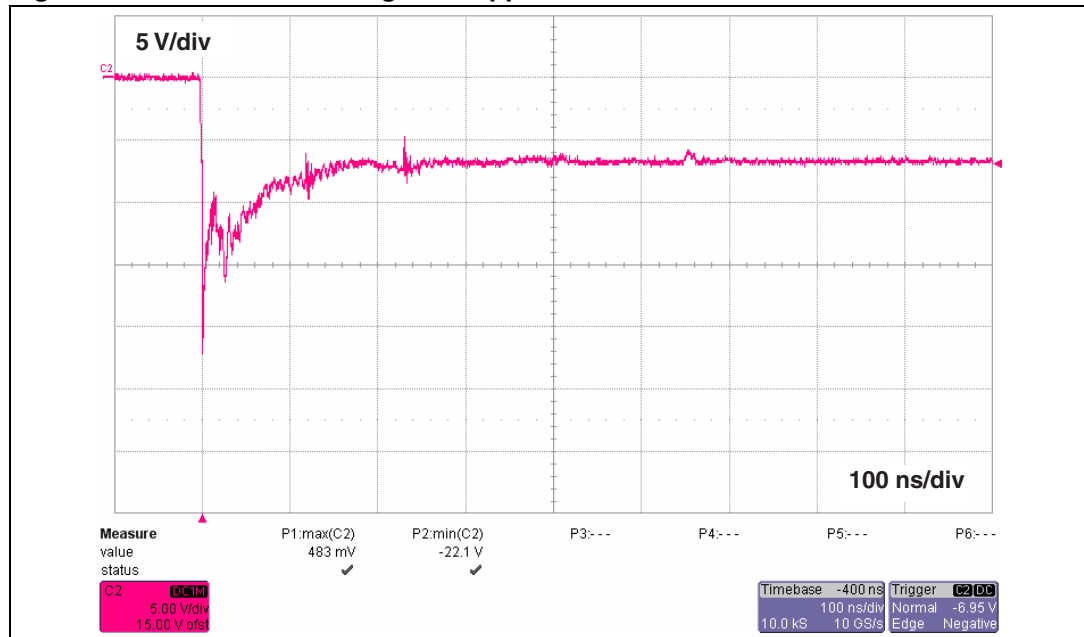


Figure 16, 17, 18 and 19 show the ESD response of SLVU2.8-8A1, respectively for +8 kV, -8 kV contact, +15 kV and -15 kV air discharges, according to IEC 61000-4-2 Level 4 standard.

The peak voltage across SLVU2.8-8A1 during a  $\pm 8$  kV contact discharge is about  $\pm 155$  V for a duration less than one nanosecond and then about a few volts.

The peak voltage across SLVU2.8-8A1 during a  $\pm 15$  kV air discharge is about  $\pm 20$  V for a few nanoseconds and then about a few volts.

## 6 Signal integrity with SLVU2.8

Figure 20. Sdd21 with SLVU2.8-4A1

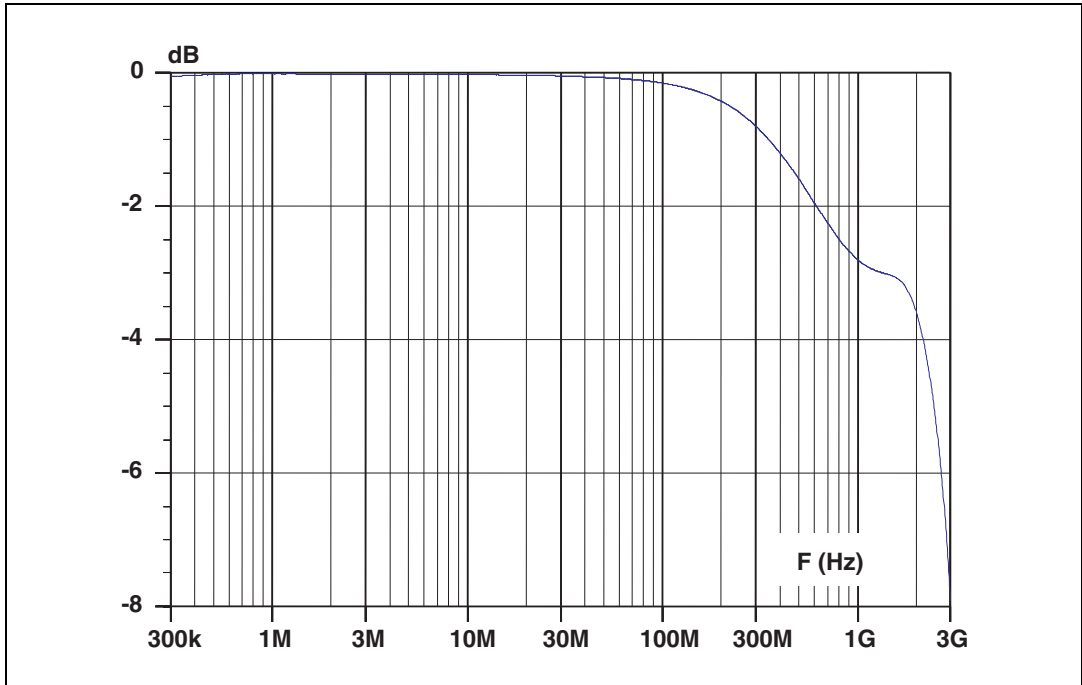
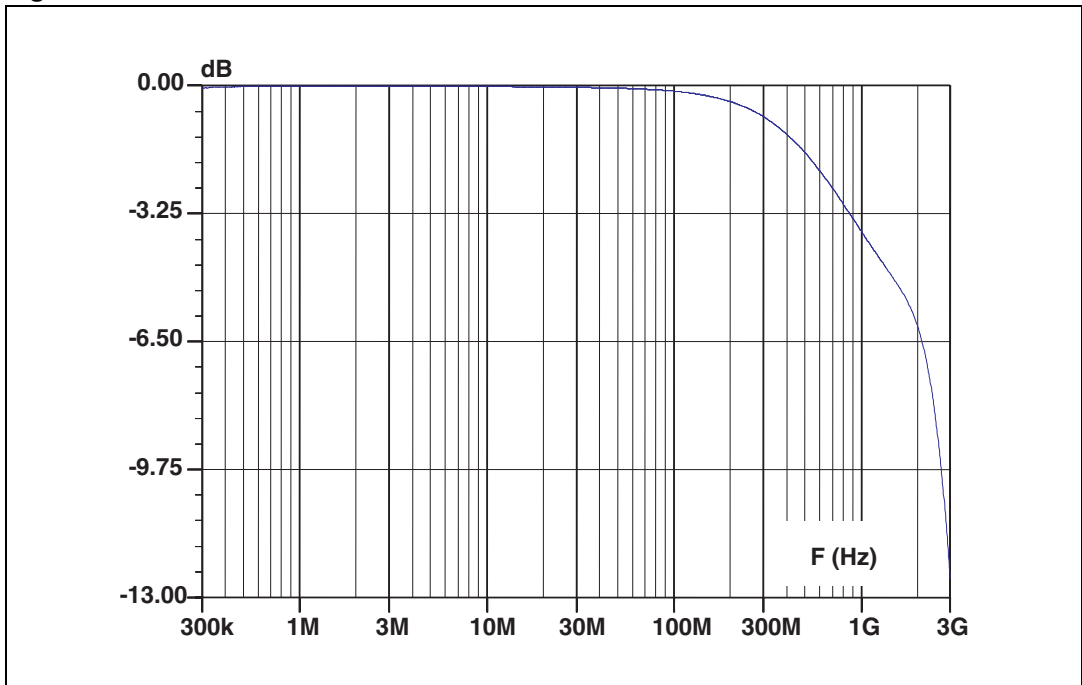


Figure 21. Sdd21 with SLVU2.8-8A1



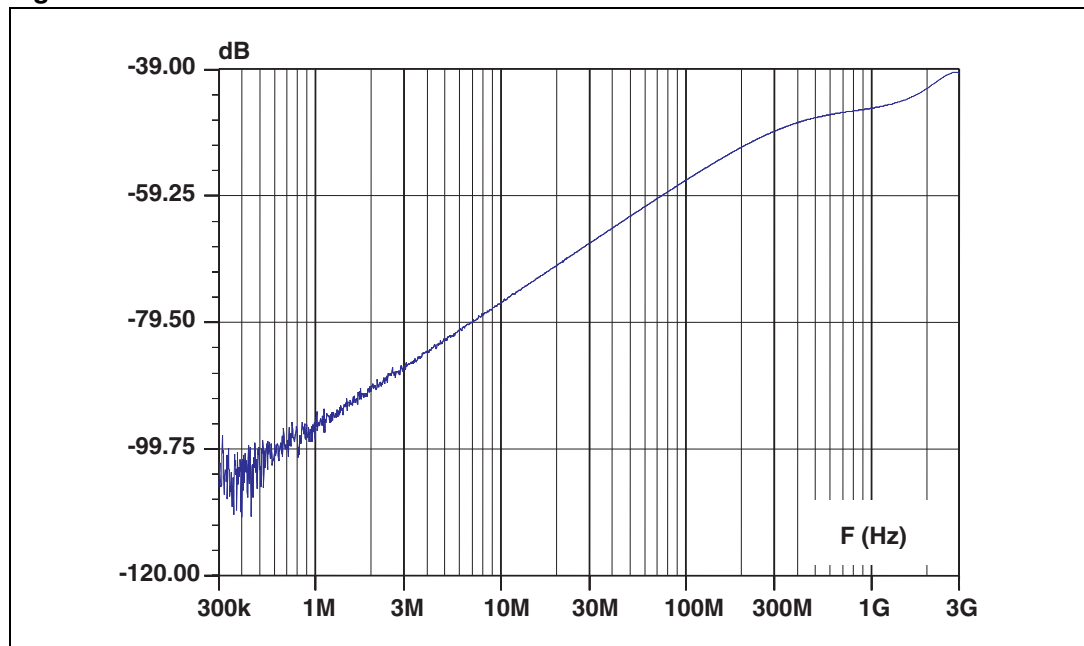
RF measurements have been performed with Agilent ENA E5071B network analyzer and Agilent N4431A calibration module.

100 Mbps and Gigabit Ethernet technologies use differential transmission. To check the signal integrity with SLVU2.8 devices, we have to consider the Sdd21 (differential insertion loss) measurement.

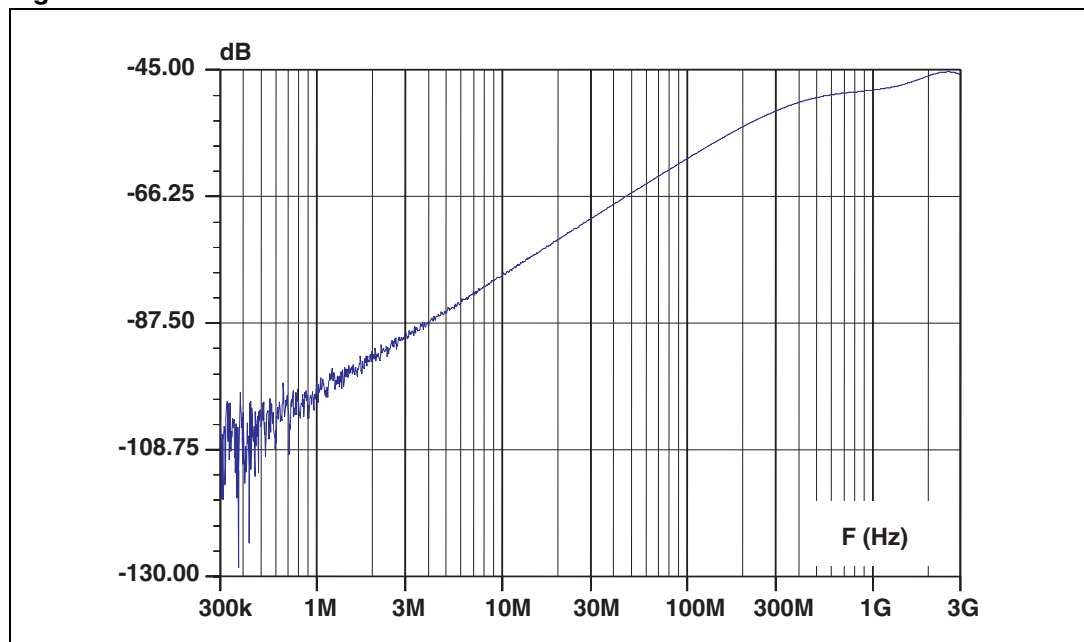
For SLVU2.8-4A1, [Figure 20](#) shows a cut-off frequency of about 1.35 GHz @ -3 dB. [Figure 21](#) shows a cut-off frequency of about 850 MHz @ -3 dB for SLVU2.8-8A1.

This is perfectly in line with Ethernet frequencies.

**Figure 22. Differential crosstalk with SLVU2.8-4A1**



**Figure 23. Differential crosstalk with SLVU2.8-8A1**

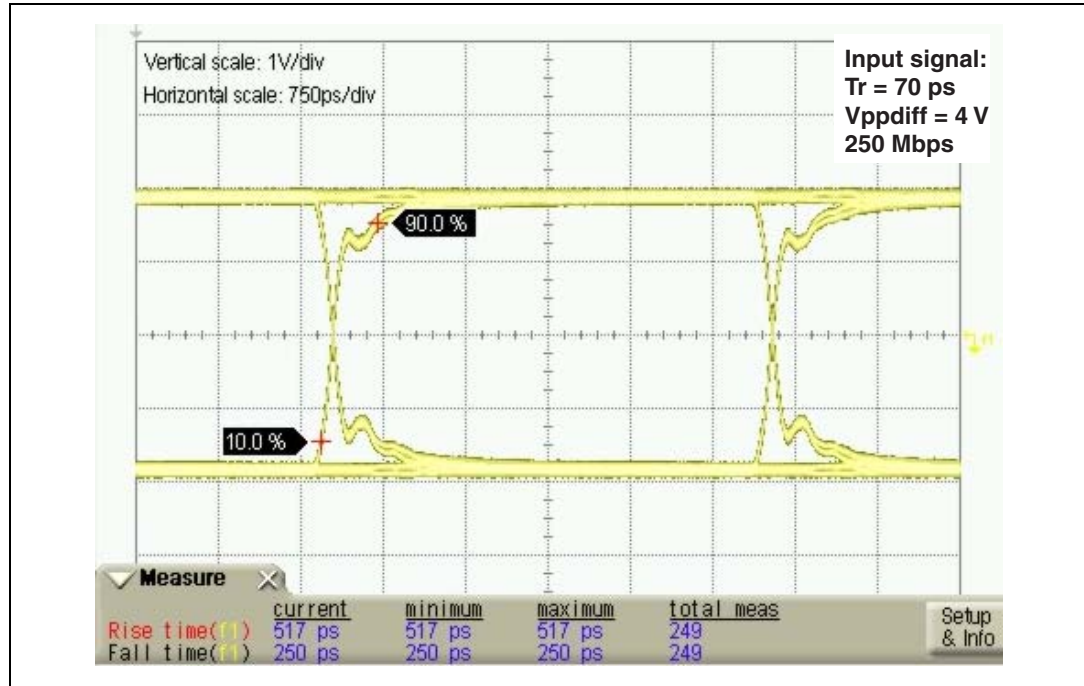




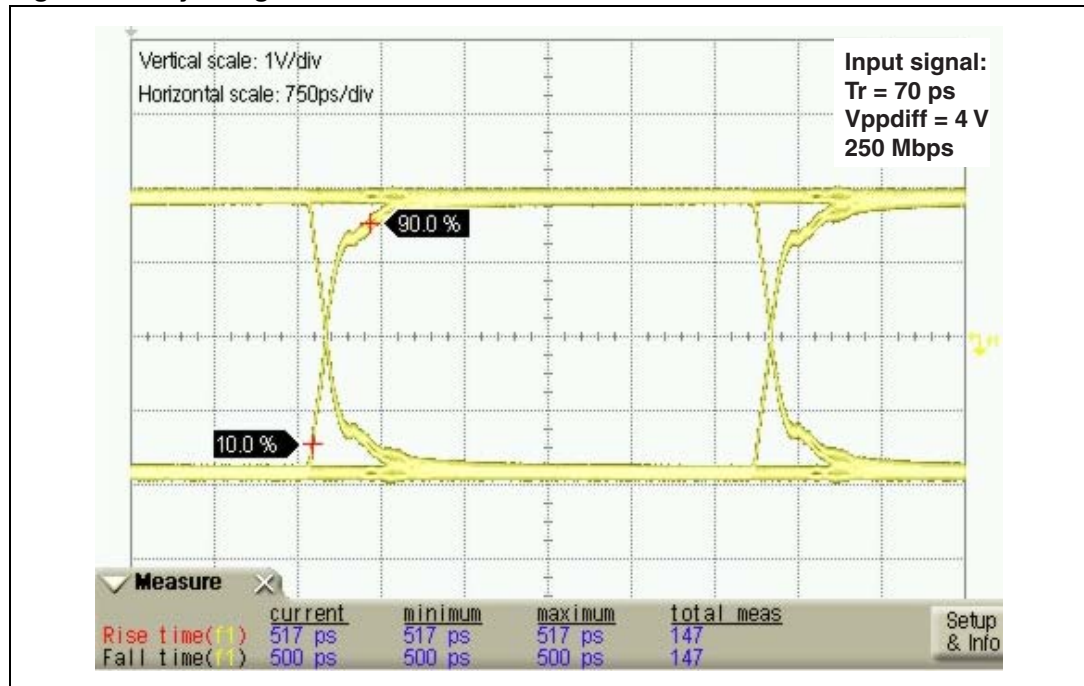
Since SLVU2.8-4A1 and SLVU2.8-4A1 devices protect respectively 2 and 4 Ethernet pairs (more than 1 pair), it is important to check that neither device generates crosstalk from one pair to another.

For SLVU2.8-4A1, [Figure 22](#) shows a differential crosstalk lower than -40 dB up to 3 GHz. [Figure 23](#) shows a differential crosstalk lower than -45 dB up to 3 GHz for SLVU2.8-8A1.

**Figure 24. Eye diagram with SLVU2.8-4A1**



**Figure 25. Eye diagram with SLVU2.8-8A1**



Eye diagram measurements have been performed with Agilent 81134A 3.35 GHz pulse / pattern generator, Agilent Infinium DCA-J 86100C digital communication analyzer and Agilent 86112A 20GHz electrical module.

*Figure 24* and *25* show the eye diagram measurements for SLVU2.8-4A1 and SLVU2.8-8A1.

Gigabit Ethernet operates at 250 Mbps (over 4 wire pairs), which corresponds to a bit time of 4 ns. This bit time of 4 ns can be clearly seen on both eye diagram measurements.

The IEEE 802.3 standard specifies a signal template for Gigabit Ethernet applications. This identifies a maximum rise time of 1 ns when the signal voltage changes from 0.7 V to 1.9 V, and a maximum fall time of 1 ns when the signal voltage changes from 1.9 V to 0.7 V.

And on both eye diagram measurements, the rise time and the fall time, which are measured between 10% and 90% of the signal are about 500 ps, which is consistent with IEEE 802.3 standard requirements.

## 7 Conclusion

Ethernet technologies on copper pairs are widely deployed on the market to support computer networking. The fastest Ethernet technologies, such as 100 Mbps and Gigabit Ethernet, are increasingly deployed to speed up the data traffic.

For these applications, protection is one of the major issues. STMicroelectronics is recognized as the major player in the telecom protection field for both wired and wireless equipment.

As far as Ethernet equipment is concerned, the SLVU2.8 concept is well adapted to protect the transceivers. SLVU2.8-4A1 and SLVU2.8-8A1 protection devices are robust enough to withstand the different kinds of disturbances encountered by such equipment. Moreover these products provide efficient protection of the Ethernet devices. Finally these products preserve signal integrity and do not disturb the normal operation of the system.

## 8 Revision history

**Table 3. Document revision history**

Date	Revision	Changes
30-Mar-2010	1	Initial release.

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